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(54) Tissue Adhesive

(57) A tissue adhesive on the basis of human or animal protein contains factor XIII and at least 33% by weight of fibrinogen, has a ratio of factor XIII to fibrinogen, expressed in units of factor XIII per gram of fibrinogen, of at least 80, contains fibrinogen and albumin in the total protein at a ratio of 33 to 90:5 to 40, contains plasminogen-activator-inhibitor or plasmin inhibitor in an amount of 250 to 25,000 KIU per g of fibrinogen, and has been lyophilized.

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(54) **Tissue Adhesive**

(57) A tissue adhesive on the basis of human or animal protein contains factor XIII and at least 33% by weight of fibrinogen, has a ratio of factor XIII to fibrinogen, expressed in units of factor XIII per gram of fibrinogen, of at least 80, contains fibrinogen and albumin in the total protein at a ratio of 33 to 90:5 to 40, contains plasminogen-activator-inhibitor or plasmin inhibitor in an amount of 250 to 25,000 KIU per g of fibrinogen, and has been lyophilized.

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SPECIFICATION

Improvements In or Relating to a Tissue Adhesive

The invention relates to a tissue adhesive on the basis of human or animal proteins, containing fibrinogen and factor XIII.

It has been known for long to use blood coagulating substances for stopping bleedings and for sealing wounds. According to the first proposals of this kind, fibrin tampons and fibrin platelets, respectively, were used. During the Second World War, tissue adherences by means of blood plasma were suggested.

In recent times, a tissue adhesive on the basis of fibrinogen and factor XIII for seamless interfascicular nerve transplantations in animal experiments has been described by H. Matras et al. in "Wiener Medizinischen Wochenschrift", 1972, page 517.

A further study was carried out by Spängler et al. in "Wiener Klinischen Wochenschrift", 1973, pages 1 to 7. Also there, the possibility was shown in animal experiments of carrying out a tissue adherence with the aid of fibrinogen as a cryoprecipitate and thrombin.

The known preparations have not yet proved satisfactory, since they do not sufficiently meet the demands set to a tissue adhesive, i.e.

a) high straining capacity of the adherences and wound sealings as well as safe and permanent blood stopping, i.e. good adhering capacity of the adhesive to the wound and tissue surfaces, as well as high internal strength of the same,

b) controllable durability of the adherences in the body,

c) complete absorbability of the adhesive in the course of the wound healing process,

d) wound healing stimulating properties.

This may partly be due to the fact that, in the known preparations, the coagulation factors necessary for blood stopping have not been present in an optimal proportion to one another, and also to the fact that the fibrinolytic activity in the area of adherence has not been sufficiently under control. Premature dissolutions of the tissue adherences frequently occurred due to enzymatic influence.

The invention aims at avoiding these disadvantages and difficulties and has as its object to provide a lyophilized tissue adhesive of human or animal origin, which meets the demands set out further above and which is present in a lyophilized form, whichis desired for its longer durability and better transporting and storing properties.

Accordingly, the invention consists in a combination of the following characteristic features:

a) that it contains at least 33% by weight of fibrinogen,

b) that the ratio of factor XIII to fibrinogen, expressed in units of factor XIII per gram of fibrinogen, amounts to at least 80,

c) that in the total protein, fibrinogen and albumin are contained at a ratio of 33 to 90:5 to 40,

d) that it has a content of plasminogen-activator-inhibitor or plasmin-inhibitor, preferably aprotinin, in an amount of 250 to 25,000 Kallikrein-inactivator-units (KIU) per gram of fibrinogen,

e) that the preparation has been lyophilized.

According to a preferred embodiment, the tissue adhesive additionally contains glycine, whereby the resolubility of the lyophilized product is improved.

Furthermore, the tissue adhesive additionally may contain glucose or sucrose, which components also improve the solubility.

The tissue adhesive furthermore may contain 0.2 to 200 International Units (iu) of heparin per gram of fibrinogen, whereby a stabilizing effect is obtained.

The tissue adhesive according to the invention possesses characteristic cross-linking properties after the dissolution, which are determinable by the sodiumdodecyl-sulphate-(SDS)-polyacrylamide-gel-electrophoresis method. The test is carried out in that, after mixing of the tissue adhesive with an equal volume of a solution containing 40 μ Moles of $CaCl_2$ and 15 NIH-units (U.S. National Institute of Health units) of thrombin per ml, the mixture is incubated at 37°C. The cross-linking degree is determined by gel electrophoresis after stopping of the reaction and reductive splitting of the disulphide bridges contained in the proteins by the addition of a mixture of urea, sodium dodecyl sulphate and β-mercaptoethanol. Typical of the tissue adhesive according to the invention is a complete cross-linking of the fibrin-γ-chains after 3 to 5 minutes, and a cross-linking of at least 35% of the fibrin-α-chains after two hours.

Fibrinogen, albumin and cold-insoluble globulin, in the total protein, are to be present in the tissue adhesive according to the invention at a certain ratio; this ratio amounts to 33 to 90:5 to 40:0.2 to 15.

The invention moreover comprises a method of producing the tissue adhesive described by starting out from a plasma cryoprecipitate, which method is characterized in that cold-soluble plasma-protein is removed from the cryoprecipitate by a single or repeated treatment with a buffer solution containing sodium citrate, sodium chloride, glycine, glucose and a plasminogen-activator-inhibitor or plasmin-inhibitor and heparin, the purified precipitate is dissolved, human albumin is added and the solution is lyophilized.

Advantageously, the cryoprecipitate has been produced of human or animal fresh plasma frozen at −20°C. When increasing the temperature to 0 to 2°C, the cryoprecipitate is gained and separated by centrifugation. The precipitate is eluted by a single or repeated elution with the buffer solution having a pH of 6 to 8.0, and centrifuged at 0 to 4°C in order to remove the

plasma-protein that is soluble in the cold. The treatment with the buffer solution is carried out until the desired factor-XIIC-fibrinogen ratio is reached.

The purified precipitate is dissolved with a further buffer solution containing human albumin, glycine and, if desired, glucose or sucrose, a plasminogen-activator-inhibitor or plasmin inhibitor as well as heparin, and having a pH of 6.5 of 9.0, and is diluted to a protein concentration of 4.0 to 9.0%. The solution is filtered through a membrane filter having a pore size of down to 0.2 μm, filled into final containers and lyophilized.

The lyophilized tissue adhesive thus obtained can be stored at room temperature or preferably at +4°C; it is ready for use after reconstitution with aqua ad iniectabilia, to which, if desired, a plasminogen-activator-inhibitor or a plasma inhibitor, preferably aprotinin, can be added. When dissolving the lyophilized preparation, attention has to be paid that the solution ready for use contains at least 70 mg of fibrinogen per ml.

The tissue adhesive according to the invention can be applied universally. It can be used for seamless connection of human or animal tissue or organ parts, for sealing wounds and stopping bleedings as well as for stimulating wound healings.

Preferred fields of application in which the tissue adhesive can be successfully used are: indications in the field of ear, nose and throat surgery, oral surgery, dentistry, neurosurgery, plastic surgery, general surgery, abdominal surgery, thorax and vascular surgery, orthopaedics, accident surgery, urology, ophthalmology and gynaecology.

Advantageously, a mixture of thrombim and calcium chloride is added to the adhesive prior to the application of the tissue adhesive according to the invention, or is applied onto the tissues to be connected.

The method of the invention is explained in more detail by way of the following example:

21 l of human plasma, which had been frozen at −20°C, were heated to +2°C. The resulting cryoprecipitate (435 g) was separated by centrifugation at +2°C and treated at +2°C with 4.3 l of a buffer solution adjusted at a pH of 6.5 and containing 6.6 g of Na_3-citrate.$2H_2O$, 3.4 g of NaCl, 10.0 g of glycine, 13.0 g of glucose.$1H_2O$, 50,000 KIU of aprotinin and 200IU of heparin per l, and again centrifuged at +2°C. The separated precipitate was dissolved in a further buffer solution having a pH of 7.9 and containing 35.0 g of human albumin, 20.2 g of glycine, 50,000 KIU of aprotinin and 200 IU of heparin per l, and diluted to a concentration of 70 mg of protein per ml.

Then the solution was sterilized by filtration through membrane filters having a pore size of down to 0.2 μm, filled into final containers at 2.2 ml each, deep-frozen and lyophilized. After reconstitution of the lyophilized product to a fibrinogen concentration of 90 mg/ml, the tissue adhesive preparation ready for use showed, in the cross-linking test, complete fibrin-γ-cross-linking after 5 minutes and 66% fibrin-α-cross-linking after 2 hours at 37°C.

The ratio of the proteins fibrinogen to albumin to cold-insoluble globulin, contained in the tissue adhesive, was determined to be 64.0:22.3:7.7. The heparin content was 4.5 IU per g of fibrinogen. Aprotinin was contained at a concentration of 1.133 KIU per g of fibrinogen. The content of factor XIII amounted to 161 units per g of fibrinogen. The total protein content in the lyophilized preparation was 72.2%, the content of fibrinogen in the lyophilized preparation was 46.2%.

The determinations were carried out in the following manner: The determination of the factor-XIII-units was performed by means of a cross-linking test, in which factor-XIII-free fibrinogen was used as a substrate and the fibrin cross-linking caused by the addition of the unknown diluted sample served as a measure for the amount of factor XIII contained therein. A corresponding calibration curve was obtained with pooled human citrate plasma, 1 ml plasma containing 1 unit of factor XIII per definitionem. The quantitative protein determinations were carried out by the method according to Kjeldahl.

The determination of the proteins relative to one another was also performed by the SDS-polyacrylamide-gel-electrophoresis method, i.e. a) with a non-reduced sample of the tissue adhesive and b) with a sample reduced with β-mercaptoethanol.

Claims

1. A tissue adhesive on the basis of human or animal proteins and containing fibrinogen and factor XIII, which tissue adhesive is characterized in that

a) it contains at least 33% by weight of fibrinogen,

b) the ratio of factor XIII to fibrinogen, expressed in units of factor XIII per gram of fibrinogen, amounts to at least 80,

c) fibrinogen and albumin are contained in the total protein at a ratio of 33 to 90:5 to 40,

d) it contains plasminogen-activator-inhibitor or plasmin inhibitor in an amount of 250 to 25,000 KIU per g of fibrinogen, and

e) it is lyophilized.

2. A tissue adhesive as set forth in claim 1, wherein the plasminogen-activator-inhibitor or plasmin-inhibitor is aprotinin.

3. A tissue adhesive as set forth in claim 1, further containing glycine.

4. A tissue adhesive as set forth in claim 1, further containing glucose.

5. A tissue adhesive as set forth in claim 1, further containing sucrose.

6. A tissue adhesive as set forth in claim 1, which contains 0.2 to 200 IU of heparin per g of fibrinogen.

7. A tissue adhesive as set forth in claim 1 being capable, after dissolution of the lyophilized

preparation, of complete cross-linking of the fibrin-γ-chains after 3 to 5 minutes of incubation, and of at least 35% cross-linking of the fibrin-α-chains after 2 hours of incubation, determined according to the SDS-polyacrylamide-gel-electrophoresis method.

8. A tissue adhesive as set forth in claim 1, wherein the ratio of fibrinogen to albumin to cold-insoluble globulin in the total protein is 33 to 90:5 to 40:0.2 to 15.

9. A method of producing a tissue adhesive as set forth in cllaim 1 from plasma cryoprecipitate, which method comprises

removing from the cryoprecipitate plasma-protein that is soluble in the cold, by treating the cryoprecipitate with a buffer solution containing sodium citrate, sodium chloride, glycine, glucose, a plasminogen-activator-inhibitor or plasmin-inhibitor, and heparin,

dissolving the purified precipitate,

adding human albumin, and lyophilizing the resulting solution.

10. A method as set forth in claim 9, wherein the cryoprecipitate is treated once with said buffer solution.

11. A method as set forth in claim 9, wherein the cryoprecipitate is treated several times with said buffer solution.

12. A method of using the tissue adhesive set forth in claim 1 for seamlessly connecting human or animal tissue or organ parts, for sealing wounds, stopping bleedings and stimulating wound healing.

13. A method as set forth in claim 12, wherein the tissue adhesive and a mixture of thrombin and calcium chloride are applied onto the tissue.

14. A method as set forth in claim 12, wherein, prior to applying the tissue adhesive onto the tissue to be connected, a mixture of thrombim and calcium chloride is added to the adhesive.

15. A tissue adhesive substantially as hereinbefore described with reference to the accompanying example.

16. A method substantially as hereinbefore described with reference to the accompanying example.

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